A.D. 1871, 31*st* JANUARY. N° 252.

Electric Telegraph Instruments.

LETTERS PATENT to Sir William Thomson, Knight, of Glasgow College, Doctor of Laws and Professor of Natural Philosophy in the University and College of Glasgow, for the Invention of "IMPROVEMENTS IN TRANSMITTING, RECEIVING, AND RECORDING INSTRUMENTS FOR ELECTRIC TELEGRAPHS."

Sealed the 21st April 1871, and dated the 31st January 1871.

PROVISIONAL SPECIFICATION left by the said Sir William Thomson at the Office of the Commissioners of Patents, with his Petition, on the 31st January 1871.

I, Sir WILLIAM THOMSON, Knight, of Glasgow College, Doctor of Laws and Professor of Natural Philosophy in the University and College of Glasgow, do hereby declare the nature of the said Invention for "IMPROVEMENTS IN TRANSMITTING, RECEIVING, AND RECORDING INSTRUMENTS FOR ELECTRIC TELEGRAPHS," to be as follows :—

The Invention consists in improvements of and adjuncts to my siphon recorder described in the Specification, No. 2147, 1867, whereby it can be used both as a sending and receiving instrument, and is also made

more sensitive and effective, more easily adjusted, and more regularly supplied with sparks.

The instrument is rendered more sensitive by having each side of the suspended or signal coil in a magnetic field. This is effected by a fixed iron core inside the coil and between the two poles of the magnet. The instrument is rendered more effective and is more easily adjusted by the application of graduated shunts to the signal coil to regulate the damping. I also facilitate adjustment by attaching the signal coil with its new iron core and suspension to a removable plate easily taken out and replaced. The adjustment of the signal coil is improved by using the torsional elasticity of stretched wires to give it directing force, which wires can be shortened, lengthened, and turned. They also serve as electrodes. I improve the suspension and adjustment of the siphon by carrying it in a similar manner. These two last adjustments allow the fibre joining the siphon and coil to be tightened.

I sometimes use a fine glass tube instead of the siphon, fixing the upper end to the ink bottle, and making the tube of such a shape that it can spring by torsional elasticity or otherwise, so as to follow the coil with sufficient freedom. In this case I keep the part of the fine tube next the ink bottle stretched in a straight line by tension of a stout fibre cemented to it at a distance of several inches, where it is bent at right angles to form the marking arm.

This improvement allows ink or other fluid to be forced through the tube by hydrostatic pressure to clean the siphon, or to mark paper for signals independently of sparks when mere pressure on the ink will not remove obstructions. I force down nitric acid or suck it up through the bottom of the tube from a vessel provided with this object. I give stiffness to the siphon in one plane by stays and put a counterpoise to diminish irregular vibrations. I conduct away ink flowing from the siphon when not in use by an adjustable vessel or reservoir, and I also provide against the accumulation of large drops of ink at the end of the siphon when no signals are being recorded by keeping the paper moving at a slow speed. The paper and statical induction apparatus are driven by an electro-magnetic engine of improved construction, and the induction apparatus is constructed so that the "replenisher" is alone used, and the electro-phorus is dispensed with. I use the armatures of my engine disposed as staves of a barrel as part of the carriers of the induction apparatus. The speed of the engine is adjusted by shunts and

added resistance. The shunts are thrown off and on by a differential motion regulated by a pendulum. I connect the engine and paper gear by a shaft steadied by vertical guides, and hanging on cords to avoid the transmission of vibrations. The speed of paper is regulated by an electric chronometer, and a punch on the wheelwork marks the time on the paper. I connect the electrified inductor with the siphon by a semi-insulating thread, which can be lengthened or shortened to oppose more or less resistance to the passage of electricity. I provide a second thread by which to drain off any excess in the supply. I use a dry pile to initiate the electrification of the inductor. The new instrument sends as well as receives messages. The same motive power and gearing is used to draw forward punched paper for signalling, and I prefer to use the same strip of paper to send and receive alternating lengths being punched and plain. The electrical connections are arranged so that the signals sent by the paper are recorded on the same paper. The paper used to send is punched into two or more rows of holes, and contact made through the holes by dead pressure between two metallic surfaces at rest a little behind the siphon. A suitable switch is provided for altering the connections from sending to receiving and the same instrument with the signal coil sufficiently shunted records the sent signals. I prefer a simple stout bar pressed against contacts as my switch. I give positive and negative signals by two contact springs, only to do this I keep the two poles of the battery constantly connected with one another through a wire of sufficient resistance, the middle of this wire being connected with the cable, and the middle of the battery with earth. If more than two strengths of battery are required for the signals a similar plan can be adopted with a greater number of rows of perforated holes in the paper, part of the instrument by which the paper is punched contains the following peculiarities:—The paper which is drawn on by a drum after each perforation begins to move gradually, and after attaining a maximum of speed comes gradually to rest. The power employed to make the perforations and to start the paper first starts a fly wheel loose on a revolver shaft, but tending to draw it on by friction. I also pull back any slack in the paper behind the drum by a spring or weight.

Thomson's Improvements in Electric Telegraph Instruments.

SPECIFICATION in pursuance of the conditions of the Letters Patent, filed by the said Sir William Thomson in the Great Seal Patent Office on the 31st July 1871.

TO ALL TO WHOM THESE PRESENTS SHALL COME, I, Sir WILLIAM THOMSON, Knight, of Glasgow College, Doctor of Laws and Professor of Natural Philosophy in the University and College of Glasgow, send greeting.

WHEREAS Her most Excellent Majesty Queen Victoria, by Her Letters Patent, bearing date the Thirty-first day of January, in the year of our Lord One thousand eight hundred and seventy-one, in the thirty-fourth year of Her reign, did, for Herself, Her heirs and successors, give and grant unto me, the said Sir William Thomson, Her special license that I, the said Sir William Thomson, my executors, administrators, and assigns, or such others as I, the said Sir William Thomson, my executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, an Invention for "IMPROVEMENTS IN TRANSMITTING, RECEIVING, AND RECORDING INSTRUMENTS FOR ELECTRIC TELEGRAPHS," upon the condition (amongst others) that I, the said Sir William Thomson, my executors or administrators, by an instrument in writing under my, or their, or one of their hands and seals, should particularly describe and ascertain the nature of the said Invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal Patent Office within six calendar months next and immediately after the date of the said Letters Patent.

NOW KNOW YE, that I, the said Sir William Thomson, do hereby declare the nature of the said Invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement thereof, that is to say :—

My said Invention consists in improvements of and adjuncts to the siphon recorder described in the Specification No. 2147, A.D. 1867, whereby it can be used both as a sending and receiving instrument, and is also made more sensitive and effective, more easily adjusted, and more regularly supplied with sparks. The instrument is rendered more sensitive by having each side of the suspended or signal coil in a magnetic field.

Thomson's Improvements in Electric Telegraph Instruments.

Figure 1, Sheet 1, shews a front elevation of the suspended coil *a*, *a*, *a*, *a*, with a fixed iron core *b*, *b*, inside it; Figure 2, Sheet 1, shews a side elevation of the same coil *a*, *a*, and soft iron core *b*, *b*; Figure 1, Sheet 2, shews a front elevation of the same coil and core similarly lettered in their position between the poles *c*, c^1, of a powerful electro-magnet; Figure 2, Sheet 2, shows a side elevation of the case A, A, containing the large magnet only, one pole *c* of which is visible in this view. The coil *a*, *a*, *a*, *a*, is made in the form of a long rectangle and is supported at *c*, *c*, so that it is moveable about the middle line parallel to the long sides. The space between the iron core and the magnet is as narrow as is consistent with freedom of oscillation for the coil.

By this arrangement I obtain the following advantages:—The force with which the coil is deflected by any given current in this arrangement is increased because by it the short portions only of the coil at the top and bottom are not effectively influenced by the electro-magnetic force. The length of the top and bottom portions of the coil can by the said arrangement be greatly reduced and so the mass and moment of inertia of the signal coil are much diminished.

The instrument is rendered more effective and is more easily adjusted by the application of graduated shunts to the signal coil to regulate what I designate the damping. This is an effect due to induction between the moving coil and the magnet, and its effect is to diminish or wholly prevent injurious oscillation in the signal coil. One method of producing this effect was described in my former Specification No. 2147, A.D. 1867. It consists in applying a shunt to the receiving coil. I now provide a set of shunt coils of graduated resistances with a convenient arrangement, whether by a plug or slide, for applying the desired degree of shunt to the moveable coil. By this means the exact amount of damping suitable to each speed of signal can be obtained. This system of graduated shunts is also convenient for assisting in the adjustment of the sensibility of the instrument. These shunts are for the sake of simplicity not shewn in the Drawing; they may be placed inside the case A, A, and are to be in electrical connection with the terminal screws *d*, d^1, shewn at Figures 1 and 2, Sheets 1 and 2. The received current enters by one of these screws *d*, and after flowing through the signal coil *a*, *a*, goes out by the other screw d^1, a portion of the received current is necessarily diverted through the shunt. Another method of obtaining the required damping is to construct the signal

coil wholly or in part of bare wire, the effect being wholly or partially to short circuit the signal coil by contact between successive layers. The advantage gained by this plan is extreme lightness of coil.

The signal coil with its soft iron core and suspension are attached to a removable plate easily taken out and replaced. This removable plate is shewn detached from the instrument at Figures 1 and 2 of Sheet 1, being lettered B, B. In Figures 1 and 2, Sheet 2, it is shewn in its place. This removable plate B, B, together with the soft iron core *b*, suspended coil *a*, connecting fibre *s*, and suspended syphon *m*, may be kept ready in duplicate to replace almost instantly that which has been in use in case of any accident, such as the clogging of a siphon.

The adjustment of the signal coil is improved by using the torsional elasticity of stretched wires to give it directing force. These wires *e* and e^1 are shewn in Figures 1 and 2, Sheet 1; the upper one can be shortened or lengthened by turning the drums *f* and slipping the little brass piece on which it is mounted up or down the slide f^1, from which it is insulated by the piece of vulcanite f^{11}. The lower wire might have a similar adjustment, but I prefer to leave the shortening and lengthening to be done at one end only, and to attach the lower end to a spring *g*, the effect of which is to limit the stress on the stretched wire and keep it constant. The directive power is given by the torsional elasticity of the wires *e*, e^1. The undeflected position of the signal coil is adjusted by turning the drum *h* on its axis, this twists the wires *e*, e^1, and turns the coil to right or left as may be desired. Three small adjusting screws h^1, h^1, are provided, by which the wire *e* may be made truly central with the pivot g^1, Figure 3, Sheet 1, and a second set of three screws h^{11} is provided by which the pivot g^1 can be made truly central relatively to the fixed iron core *b*, *b*. With these adjustments the space between *b*, *b*, and *c*, *c*, can be made much smaller than would be possible without them. The wires *e*, e^1, also serve as electrodes or terminal wires to the signal coil, and are connected by suitable helixes *l*, *l*, with the insulated terminals *d*, d^1. I improve the suspension and adjustment of the siphon by carrying it in a similar manner, that is to say, upon a wire stretched in torsion. The long leg of the siphon is lettered *m*, and its short end *n* dips into the reservoir D. The siphon is carried by a little saddle n^1 which supports the horizontal limb thereof, and is attached to the stretched wire *o*, o^1, held tight by springs o^2, which can

be turned round, thereby twisting the wire by the torsion heads p, p^1. The brass frame q, q^1, is capable of adjustment by turning on the axis r, which is at the same time a pinching screw. The whole system q, q^1, siphon m, m^1, and stretched wire o, o^1, can be moved in or out relatively to the plate B, B, by slipping it between the nut r and the support r^1, but firmly held by the screw r and nut when the adjustment is complete. The fibre joining the siphon and signal coil is lettered s, Figure 2, Sheet 1. The instrument is adjusted as follows :—Lengthen or shorten the wires e, e^1, to give the required rapidity of oscillation, make the wire e central with the point g^1, make the point g^1 central with the iron core b, b, turn the torsion head h in such a direction as would tighten the fibre s, turn the torsion heads p, p^1, in such a direction as would tighten the fibre s, also move out the frame q so much as will tighten s sufficiently to bring back the siphon to a mean vertical position and the coil a, a, to the central position shown in the Drawing; if the fibre s brings the siphon back to the vertical before bringing the coil a, a, a, a, to its central position undo a little of the twist given by the torsion head h, and vice versa. I sometimes use a fine glass tube instead of a siphon, fixing the upper end to the ink bottle and making the tube of such a shape that its marking arm can spring by torsional elasticity or otherwise so as to follow the oscillations of the signal coil with sufficient freedom. In this case I keep that member of the fine tube next the ink bottle stretched in a straight line by the tension of a stout fibre connected to it and extending from the point where the tube is bent at right angles to form the marking arm. This arrangement is shewn in side elevation at Figure 4, Sheet 1, and in front elevation at Figure 5, Sheet 1, where A represents the ink bottle, B the fine glass tube, of which b is the marking point, c the portion which springs by torsional elasticity, and d the stout fibre coupling the tube to the arm e. The tube may be fitted to the ink vessel by a tube of thin sheet india-rubber or similar material, or the tube may as shewn in the Drawing be rigidly cemented into the ink bottle, its own flexibility giving sufficient mobility to the outer end. The fibre connecting the marking arm with the signal coil may, as is shewn at Figure 5$^{\times}$, be prolonged and provided with a very light spring of sufficient resilience for the purpose of keeping the connecting fibre tight during all its motions. I sometimes give stiffness to the siphon or tube by stays. If in any case the mobility in the plane of the paper is found too free with a round tube greater rigidity can be given by making the tube of oval section, or other arrangements of a stretched

fibre acting as a stay or stays, as shewn at Figures 11, 12, and 13, may be used.

Another method of arranging the marker is shewn at Figure 13×. *a* is a fine marking arm cemented into a somewhat coarser horizontal branch projecting from a glass siphon *b*. This siphon is supported so as to be capable of turning round its long vertical leg. The mode of support is by two stretched wires or fibres pulling in opposite directions. The axis of motion is in this plan vertical. The fine marking arm is about as fine as a fine sewing needle. The coarser arm and siphon is of glass tube just wide enough to let the fine arm slip in. The fine marking arm may be pulled out in case of choking, and another slipped in and cemented with wax at any moment. While giving greater effective rigidity in the plane perpendicular to the paper it will give either unchanged mobility or less mobility, or greater mobility of the tube parallel to the paper according as its fixed end is in a certain line perpendicular to the length of the tube or nearer the outer end, or further from the outer end. When the single stay is used its fixed end is adjusted to give the desired mobility to the outer end of the tube and the proper tightness of the stay.

This improvement allows the plane of the arc along which the marking end of the tube moves in virtue of the signals to be horizontal instead of vertical as it necessarily is with the siphon if of simplest form and smallest amount of inertia attainable, and it also allows when desired the signals to be first shewn on the portion of the paper where it is running horizontally.

This improvement further allows ink or other fluid to be forced through the tube by hydrostatic pressure to clean the tube or to mark paper for signals independently of sparks. In many cases, for instance, in rapid signalling with powerful currents through land lines, the requisite pressure for good marking whether with or without electrification of the syphon may be that due to from one to three or four inches' head of the liquid. In all such cases this pressure is most conveniently obtained by having free communication of air pressure between the atmosphere and the free surface of ink in the ink vessel, that is to say, by having the ink vessel either open or closed by a cover not perfectly air-tight. When a greater constant pressure is desired than can be easily thus obtained I produce the requisite pressure either by gravity acting on a column of mercury or by air or other fluid pressing on the

free surface of the ink, or by a piston, or by a flexible part of the ink bottle acted on by force properly applied from without. The column of mercury is preferable in respect of constancy. I also apply hydrostatic pressure to free the tube from obstructions. If the tube becomes clogged at any time so as to impair the marking the obstruction is often removable by fluid pressure forcing the ink to flow through it. This cannot be done easily for the siphon otherwise than by the operator's sucking the lower end of it by his mouth, a delicate operation involving the probability of breaking the siphon. With the fixed tube various methods can be adopted by which it may be cleared with much greater force with perfect safety to the tube and without any dexterity on the part of the operator. One of these is as follows:—I apply an air syringe of small bore to the upper part of the ink bottle, which if ordinarily open to the air is to be closed for the occasion by a proper plug or stop-cock. Any degree of air pressure required is then readily applied to the free surface of the ink.

Another method is by a reservoir of mercury connected by a flexible tube to one branch of a **U** tube, the upper portion of the other branch of which is in hydrostatic communication with the ink vessel either through the liquid itself continued to the surface of the mercury or through a portion of air intervening. A much greater pressure than can be obtained by blowing with the mouth can be easily provided by raising the reservoir of mercury at any time through the spaces of a few inches or feet. The mercury reservoir may be left ordinarily in such a position as to give the proper pressure for regular marking, but at any time (in case of suspected clogging for instance) it may be instantly raised or lowered so as to produce a largely increased or largely diminished pressure. When mere pressure on the ink will not remove obstructions I force down nitric acid or suck it up from the bottom of the tube from a vessel provided with this object. This is most easily done by applying (with the aid of the apparatus above described) nitric acid to the marking end of the tube, and drawing a very small quantity of that fluid through the tube, either by a syringe acting as a drawing air pump or by a mercury vessel lowered several inches below the level of the tube. I put a counterpoise to the siphon, preferably attache don the aluminium carrier on the side remote from the marking arm of the siphon to diminish irregular vibrations. This counterpoise, which may be of wax, is attached to the carrier n^1, so that the centre of inertia

of the siphon *m* and the carrier with counterpoise may lie on the axis round which the whole turns. This has two advantages, first, diminishing the tendency to irregular vibrations caused by tremors transmitted through the framework, whether from the moving gear or from disturbances in the neighbourhood, such as are experienced when the instrument is used in a crowded city, in a factory, or at sea. Second, checking the disturbance of signals caused by the motions of the ship when the instrument is used at sea.

I conduct away ink flowing from the siphon when not in use by an adjustable vessel or reservoir, not shewn in the Drawings. In order to admit of the introduction of this reservoir, and for other purposes, it is necessary that there should exist an arrangement for drawing back the paper from the siphon point. This arrangement is shewn in Figure 1, Sheet 2. The paper follows the line 1, 1, 1, 1, being drawn only by the roller *t* driven by suitable gear from the prime mover, namely an electro-magnetic engine herein-after described. Just before reaching this roller *t* the paper passes over the shield *w*, and this shield can be drawn back or pushed forwards by the screw and thread w^1, which on being turned causes the shield *w* to slide backwards or forwards. This mechanism is shewn in enlarged detached views at Figures 1 and 2, Sheet 3. The paper can also be adjusted laterally by moving the whole bracket E, E, outwards and inwards on the frame F; this gives an adjustment in a plane at right angles to that in which the head w^1 causes the paper to move.

I also provide against the accumulation of large drops of ink at the end of the siphon or tube when no signals are being recorded by keeping the paper moving at a slow speed. I drive the drawing-off roller as follows:—A small V pulley 3, Figures 1 and 2, Sheet 2, is placed on the shaft of a prime mover 2, a belt passing round 3 drives the large pulley 4 on the shaft 5, a belt from a small pulley 6 on the shaft 5 drives the pulley t^1 on the shaft of the paper roller *t*. Or, instead of this arrangement, I prefer to use that shown at Figures 6 and 7, Sheet 3, wherein the paper roller *t* is driven by means of a clutch *q*, and this allows the paper to be moved at a slower rate than obtains with the mechanism previously described. The clutch *q* admits of being thrown back, so as to release the shaft on which the roller *t* is fixed by means of the lever *r*, Figures 6 and 7, Sheet 3, and then becomes engaged with a toothed pinion q^1, which drives a spur wheel q^2

on a secondary shaft q^3, a pinion q^4 on which again drives a spur wheel q^5 on the shaft of t, which is then driven at a much slower speed. I prefer to let the shaft 5 be entirely supported by two belts having only lateral guides to keep it in its place. This arrangement diminishes friction and prevents the transmission of mechanical vibrations from the prime mover to the paper.

The paper and statical induction apparatus are driven by an electro-magnetic engine of improved construction, shewn at Figures 6 and 7, Sheet 1. This engine consists of a series of bars of soft iron *a*, *a*, *a*, arranged like the staves of a barrel but separated from one another by insulating material, and successively attracted by the electro-magnet A. The make and break apparatus by which the electro-magnet is caused to attract the successive bars or armatures *a*, *a*, *a*, at the proper time is shewn in detail at Figures 8, 9, and 10, Sheet 1, and its position in relation to the electro-magnetic engine is shewn at Figures 6 and 7 thereof. The circuit of the electro-magnet is complete when contact is made between the platinum knob *c* attached to the spring *d* and the platinized contact piece *e*, which are at other times insulated from one another by the vulcanite piece *f*. The moveable contact piece is a short piece of stout platinum wire *c* soldered near one end of an approximately straight steel spring *d*. This end of the spring is reduced to a round pin *x* in line with the middle line of the spring and projecting to a short distance beyond the platinum contact piece. The other end of the spring is attached to a fixed insulated piece of metal *g* with which it is in metallic communication, and through which it forms part of the circuit, which is completed when the moveable contact piece *c* is allowed to press on the fixed contact piece *e* by the projecting pin *x* being let down by the cam A. The line of the spring is parallel to the axis of the electro-magnetic engine, and its plane of motion passes through this axis. The cam lifts the projecting pin *x* to break contact, and leaves it free at the proper times to make contact by its own elastic force. The spring *d*, which is approximately straight, either when making contact or when lifted through the small space of the cam's action on it is under considerable elastic strain. When dismounted and allowed to take its unstrained shape it is curved. In this state the curvature ought if the flexual rigidity of the spring is uniform throughout to be approximately in simple proportion to length along the curve from the end which is fixed when the spring is in position. This condition is easily fulfilled with sufficient approximation to accuracy by giving the spring

a proper set, so that when mounted it is found to be nearly enough straight and to press with sufficient force against the fixed contact piece to secure good contacts. This disposition is such that the motion of the spring is in a plane perpendicular to that of the cam, the form of the spring approximately straight, and the point of pressure of the cam very close to the moveable contact piece. A screw *w* is used to lift or lower the spring *d* and thus adjust the length of contacts. The time when contact is made is adjusted by turning round the cam A on the axis and fixing it in the required position by set screws *i* and *j*. The bearings of the electro-magnetic engine should be constructed so as to cause very little friction, and I attain this end by supporting the pivots of the main shaft *b*, *b*, Figure 6, Sheet 1, on rollers *d*, *d*; each pivot is prevented from slipping off the roller by two smooth parallel guides between which it plays easily. Motion of the shaft in the direction of its axis is checked by two hard plates x^1 fixed perpendicular to its axis at a distance asunder slightly greater than its length. The antifriction rollers *d*, *d*, each of one piece of steel, are of the shape shewn in the Drawings. They are kept in position by end plates similar to those herein-before described for the main shaft *b*, *b*. Each of the rollers *d*, *d*, dips into an oil vessel and carries oil round sufficiently to keep its own pivots and the pivots of the main shaft constantly oiled. The guiding cheeks of the main shaft and the bearings of the antifriction rollers are so placed that during the action of the instrument the pivots of the main shaft press each of them only on one of these guides and on the antifriction roller, but with much more force on the antifriction roller than on the guide. It need press with no more force on the guide than to prevent it from leaving that guide and moving over to the other under the influence of the varying force to which it is subjected through the successive electro-magnetic attractions. I regulate the speed of revolution by adding or subtracting resistance from the circuit of the electro-magnet, and I sometimes diminish the spark at the contact piece *e* by using a permanent shunt connecting the ends of the electro-magnet's coil. The induction apparatus is constructed so that the replenisher is alone used, and the electro-phorous described in my Specification, No. 2147, 1867, is dispensed with.

I use the armatures of my engine disposed as staves of a barrel *a*, *a*, *a*, Figures 6 and 7, Sheet 1, as part of the carriers of the induction apparatus, the other part being a series of brass strips *f*, *f*, *f*, (Figures 6 and 7) attached to the soft iron staves.

The action of the replenisher is as follows:—E, Figures 6 and 7, is a plate in connection with the earth. B is an insulated plate from which the electricity of high potential is taken to the siphon. Four springs *g*, *h*, *i*, *k*, the last being shewn by a dotted line only, are arranged so as to make the contacts herein-after described; the carriers *a*, *a*, *a*, *a*, are moving in the direction of the arrow. 1°. When a carrier *a* first comes under the cover of the insulated plate B which is, say, positively electrified it is electrically connected with the plate B by the spring *g* making contact with the metal bar a^1 attached to *a*; any positive electricity on *a* then flies to B. 2°. When the same carrier *a* has moved further so as to be completely covered by the plate B the contact with the spring *g* is broken, and a little later a fresh contact made with the spring *h*, and a diametrically opposite carrier *a* is by the spring *k* at the same time joined to the carrier *a* first referred to, and being covered by the earth plate E the said carrier *a* becomes by induction positively electrified while the opposite carrier is negatively electrified. 3°. After the two contacts with *h* and *k* have been broken the carrier *a* now negatively charged is put into connection with the earth and discharged by the spring *i*. 4°. The same carrier is in its turn positively charged by the spring *k*.

In place of the electro-magnetic engine herein-before described I sometimes employ as my prime mover a magnetic engine of the arrangement illustrated at Sheet 7 of the accompanying Drawings, whereon Figure 1 is a section partly in elevation thereof; Figure 2, an elevation of that end marked A, Figure 1; Figure 3, an elevation of that end marked B, Figure 1; whilst Figure 4 is a detached view of the vulcanite disc G shewing the arrangement of the carriers *a* situated thereon. This engine consists of one bar or of a series of bars of soft iron compactly packed together situated in the interior of and extending the full length of the cylindrical casing A, which is attached to the engine shaft B, as shown at Figures 1 and 2. The casing A is so situated in the interior of a powerful cylindrical compound magnet C that as the engine revolves the opposite ends of the soft iron bars contained in the casing A are alternately brought under the influence of the opposite poles of the said magnet C.

The make and break apparatus by which the magnet is caused to attract the opposite ends of the soft iron bars alternately is more particularly shown at Figures 1 and 3. The moveable contact pieces by

which the current is alternately made and broken consists of a series of springs arranged in two sets, D and E. Each of these sets are arranged after the manner of the teeth of a comb, and are made to bear upon the periphery of the drum F, which is situated upon the engine shaft B, as shewn. At two points in the periphery of the drum F diametrically opposite to each other and in the plane of the soft iron bar strips of agate or other insulating material are inserted, as shewn, which when brought round by the revolutions of the drum F so as to be in contact with the springs D and E thereby break the metallic connection and therewith the attractive influence of the magnet upon the end of the soft iron bar is reversed.

The induction apparatus is constructed and arranged in the following manner:—Upon a vulcanite disc G the carriers *a*, *a*, are arranged, as shewn at Figures 1 and 4. The disc G and carriers *a*, *a*, are partially enclosed by a metallic casing, but which is insulated from the carriers *a*, *a*, by means of a thin vulcanite lining *b*, as more particularly shewn at Figure 1. This metallic casing is constructed in two parts, as shewn at Figure 2, one side of which, namely, that marked $E^{\times}$, is in connection with the earth, whilst that marked $D^{\times}$ is completely insulated, and from which the electricity to the siphon is conducted, the manner whereby the electricity is drawn from the earth plate E and discharged on to the insulated plate B being in every respect similar to that employed for the same purpose with the electro-magnetic engine herein-before described, namely, through the medium of the springs *g*, *h*, *i*, and *k*, as arranged and shewn at Figure 2. I use a dry pile contained in the vulcanite chamber X, Figures 1 and 2, Sheet 1, and Figures 1 and 2, Sheet 2, to initiate the electrification of the inductor B. I connect the electrified inductor B with the siphon by a metallic conductor W, Figures 1 and 2, Sheet 2, and a semi-insulating thread *v*. The conductor W leading from the inductor B rests upon the shaft u^1, upon which the drum Y is carried. When the conductor W becomes overcharged with the current a portion of it may be drawn off by placing the wooden arm W^1 in contact with or very close to the little wooden stud *l* attached to the under side of the conductor, and thus a portion of the current is diverted, the remainder or non-diverted portion passing on constantly by a semi-insulating thread *v*, which can be lengthened or shortened to oppose more or less resistance to the passage of electricity. The mode of attaching, lengthening, or shortening this thread *v* is shewn in

Figures 1 and 2, Sheet 1, and at Figures 1 and 2, Sheet 2. The one end of the thread is attached to the metal shaft *u* bearing a vulcanite cylinder F having a deep screw cut on it. The other end of this thread *v* is attached to a small metal drum Y acted on by a spring like that of an ordinary pocket measuring tape. By turning the vulcanite drum the thread is wound upon it and pulled out from the metal drum, so as to augment the resistance as in Wheatstone's "rheostat." When the vulcanite drum is turned in the other direction the spring draws the string round the metal drum and the resistance is diminished. If the smallest resistance thus obtained when the two drums are conveniently placed is found to be too small, the part of the thread remaining unwound between the vulcanite drum and the metal shaft of the vulcanite drum may be impregnated with salt or even replaced by a fine metallic wire. A second thread may similarly be used between the plate B and earth to draw off an excess of electricity. The speed of the engine, as has been stated above, is regulated by shunts and added resistance. The shunts where chronometric accuracy is desired are thrown off and on by a differential motion regulated by a pendulum. Instead of shunts added resistance might obviously be treated in the same manner. The mode by which the shunts are thrown off and on is shewn in Figures 1 and 2, Sheet 4. The shaft *a* is called the chronometer shaft. It rests on two anti-friction rollers *f* and *g* attached to one long shaft *h* (which may be supported on ordinary bearings) below it. It bears upon these rollers by two other rollers *i* and *k* coaxial with itself. The roller *i* is rigidly attached to the chronometer shaft, the other roller *k* is attached to a tube *l* mounted on this shaft *a* by means of a collar at one end of the tube, and a bearing at its other end for one terminal pivot of the chronometer shaft *a*. The four rollers *f*, *g*, *i*, and *k*, are of such dimensions as to give the tube *l* such a differential motion that it goes round somewhat faster than the chronometer shaft. I find that something from five to ten per cent. faster than the chronometer shaft gives good results. A second tube *m* fitting between two collars on the chronometer shaft is placed close to the tube *l*, and is carried round by two spring clips *n* pressing it externally, or other suitable friction gear may be employed. This second tube *m* when unchecked is carried round as if rigidly connected with the first tube, but it can be checked with ease so as to be altogether stopped at any time. When it is released the friction is sufficient to set it very suddenly in motion again with the same speed as the first tube. The second tube *m* carries one or more arms *o*, *o*, *o*,

which act upon a pendulum *p* through a pallet or pallets after the manner of the teeth of a dead beat escapement wheel, as shewn at Figure 4, Sheet 4. They keep the pendulum *p* vibrating, and at each impact on the dead face of the pallet the rotation of the tube is checked sufficiently to prevent more than one arm from passing for every period of the pendulum. Thus, if a "half seconds" pendulum be used, that is to say, a pendulum whose period is one second, and if the second tube *m* is to turn once round in six seconds there must be six arms, or if it turns once round in five seconds there must be five arms, as shewn in the Drawing. These arms might be rigid like the teeth of an ordinary escapement wheel, so that the arrangement would simply be an escapement wheel loose on the chronometer shaft and influencing it in the manner described below; but I prefer making the arms elastic to prevent damage in case of any of them being taken aback by the pallet, and also to regulate the motive force applied to the pendulum by each arm in escaping the pallet. There may be either two pallets arranged just like those of the ordinary anchor of the dead beat escapement, or there may be only one pallet, one side of the anchor as it were being cut away. When only one pallet is used the plane of motion of the arm may very conveniently be perpendicular to the plane of motion of the pendulum, which gives an arrangement preferable in point of simplicity to other more common or obvious transformations of the general plan described above. Another fixed spring *s* is similarly kept in communication with a metal ring *r* rigidly attached to the chronometer shaft *a*. The rim of this ring is composed partly of metal and partly of insulating material, as seen in Figures 1 and 2, Sheet 4, and is touched by the spring *t*, Figure 1, Sheet 4, carried by the escapement wheel or tube *m*. By insulating materials properly placed these two springs *s* and *t* are cut off from metallic communication through the moving parts which have been described, except when the spring *t* carried by the escapement wheel is in contact with the metallic part of the rim on which it presses. One or other of the springs *s* and *t* may be in metallic communication with the chronometer shaft and the two tubes *l* and *m*, but I prefer insulating all the pieces of metal which are in connection with either of the fixed wires by vulcanite or other proper material, so as to prevent metallic communication between them and the shaft and tubes. The two springs *s* and *t* are connected to the two ends of the coil of the driving electro-magnet A, Figures 6 and 7, Sheet 1, by electrodes of proper resistance to fulfil the following con-

dition. When the second tube *m* is in such a position relatively to the main shaft *a* as to make contact the coil of the electro-magnet is shunted so as to reduce the driving power sufficiently for the purpose of regulation. For example, if the resistance in the electrodes and moveable contact pieces which have been described is infinitely small, the driving power would be altogether stopped when the contact referred to is made. But this would be a more abrupt controlling action than is desirable. In most cases I prefer to arrange so that the resistance in the shunt shall be several times greater than the resistance in the electro-magnet, and I secure that the controlling action shall be sufficient by adjusting the rate approximately by the method above-described. All that is necessary to secure this condition is that without the regulating shunt the chronometer shaft would attain a speed greater than the proper speed, but that when the shunt is applied the power is insufficient to maintain the proper speed.

In connection with my instrument I sometimes employ a chronometer for the purpose of indicating the time at which a message is being transmitted or recorded. The position which the said chronometer occupies in relation to the other parts of the instrument is shewn on the general arrangement Drawings, Figures 1 and 2, Sheet 2, whilst its constructive features are more particularly illustrated at Figures 3, 4, and 5, Sheet 3, which are respectively a side elevation, plan, and end elevation thereof.

Under the arrangement shewn a pinion a^1 fixed upon the spindle of the paper roller *t* is placed in gear with the first wheel *b* of the chronometer train, the number of teeth in the wheel and pinion being such that with the rate at which the pinion a^1 is driven the wheel *b* is caused to make a complete revolution in exactly five minutes, in accordance wherewith its flat face is divided into five equal spaces numerically marked, as shewn at Figure 3, Sheet 3. Co-axial with the wheel *b* a pinion *d* is fixed, which is geared into a wheel *e*, the number of teeth in the pinion *d* being to the number of teeth in the wheel *e* on the ratio of one to twelve. The wheel *e* thus makes a complete revolution in one hour. In like manner a pinion *f* upon the same axis as the wheel *e* is geared into another wheel *g*, and the ratio of the number of teeth in their respective circumferences being as one to twenty-four, the wheel *g* makes a complete revolution in twenty-four

hours. Upon the flat face of the wheel *g* a drum *h* is fixed concentric therewith, the outer surface of which is divided into hour units, and numerically marked in succession, as shewn at Figure 3, Sheet 3; its outer rim *i* is correspondingly divided, and at each division has a type or types situated thereat indicating numerically the successive hours. As the strip of paper 1, upon which a message is to be recorded or which may be employed as the medium of transmission, according as the instrument is employed for either sending or receiving signals, is drawn along in contact with the lower surface of the drum *h* in the direction indicated by the line 1 and by the arrows at Figure 3, each hour in succession is stamped thereon, that being effected by means of a stud *k* attached to the wheel *e* being at a point in each successive hourly revolution brought into contact with and depressing a lever *l*. Immediately that the stud *k* has passed out of contact with the lever *l* a hammer *m* fixed upon the extremity of a lever *n* is forced upwards by means of the resistance of a spring n^1, so as to strike the paper 1 against the periphery *i* of the drum *h*, whereby it receives an impression from the type or types situated thereon, the said impression recording numerically the hour of the operation, and each successive hour is similarly recorded, minutes being read off at *x* upon the wheel *b*.

The new instrument sends as well as receives messages. The same motive power and gearing may be used to draw forward punched paper for signalling, and I sometimes use the same strips of paper to send and receive messages, alternative lengths of the paper being punched and plain. The electrical connections are so arranged that the signals sent by the paper are recorded on the same paper. The paper used to send is punched into two or more rows of holes as herein-after set forth and contact made through the holes by dead pressure between two metallic surfaces C and D and springs *x* and *y*, as shewn at Figures 6, 7, and 8, Sheet 3. These contacts may be made a little behind the siphon or elsewhere. A suitable switch is provided for altering the connections from sending to receiving, and the same instrument with the signal coil sufficiently shunted records the sent signals. I prefer a simple stout bar F, Figures 7 and 8, Sheet 3, pressed against contacts as my switch. I give positive and negative signals by two constant springs *x* and *y* only. To do this I keep the two poles of the battery constantly connected with one another through a wire S, Figure 8, Sheet 3, of sufficient resistance,

the middle of this wire being connected with the line as shewn, and the middle of the battery with earth.

The diagram, Figure 8, Sheet 3, shews the proper arrangement of connections for sending and receiving as above described. The diagram, Figure 9, Sheet 3, shews the punched paper. The part of the instrument by which the paper is punched contains the following peculiarities:— The paper which is drawn on by a drum after each perforation begins to move gradually, and after attaining a maximum of speed comes gradually to rest. The power employed to make the perforations and to start the paper may first start a fly wheel loose on a revolving shaft, but tending to draw it on by friction. I also draw back any slack in the paper behind the drum by a spring or weight. The part of the instrument by which the paper is punched is shewn in Sheet 6 constructed to suit the Steinheil system with perforations in two rows. The same plan with obvious enough changes of detail is applicable to perforate the paper for other modes of signalling which may be desired; in any case I use three levers A, B, and C, which according to usage will often be called keys. One of them, C, I call the space key, another the dot key, and another the dash key, the recent submarine usage having applied the name of dots and dashes in submarine signalling to left and right motions of the marker. When any one of the three keys is depressed and allowed to rise it causes a shaft D, which I call the revolver, to turn through a certain angle either a complete turn or any submultiple of a turn. I now describe the details on the supposition that as in the Drawing it is a complete turn. This shaft D during a definite part of its revolution acts upon the paper drum F so as to cause it to commence gradually moving and after having attained a maximum velocity to gradually cease moving, when it has reached a perfectly definite position. This effect is produced by a pin *f* carried round by the revolver so as to enter a radial notch or slot in a disc E co-axial with the paper drum moving radially when it enters and leaves the slot. To make sure that the paper drum F does not move except through the action of the revolver a clutch not shewn in the Drawings checking it in exactly the proper position may be appended. Further this clutch may be so arranged that if through want of absolute truth in the mechanism the position in which the paper drum is left by the pin be not precisely correct the drum may be moved forwards or backwards so as to bring the paper to its precisely correct

position ready for the punch. Lastly. To make sure of the very definite action of this clutch it is desirable that the surfaces of the V notch on which it acts should be inclined at an angle smaller than a right angle. To get the best result I therefore sometimes add an application by which the clutch is lifted through the action of the key shortly before the instant when the pin of the revolver enters the radial slot, or this clutch may be dispensed with. But a good result may be obtained more simply by inclining the faces of the V differently to the radius through their intersection, and arranging the line of motion of the clutch so that it cannot jamb either when it is pressing the wheel back or when the wheel by moving forward lifts it. The mode in which each key acts on the revolver is as follows, the key being supposed to be approximately horizontal and the motion of each acting part approximately vertical:— When the key is pressed down it presses upon a treadle H, which like that of a foot lathe works on the revolver shaft through something less than half of its revolution, which may be continued and completed through inertia, or by the action of springs as hereinafter set forth. The clutch dropping into the V notch stops the revolver shaft sharply enough in its proper position for the next action of any of the keys. The notch may be sufficiently obtuse to allow the clutch to be lifted as by a cam by one side of the V when a fresh action of one of the keys turns the revolver. The inertia by which in one form of my instrument a complete revolution of the revolver in a sufficiently short time is secured is that of a fly wheel, not shewn in the Drawings, loose on the revolver shaft but acting on it through friction. This friction is best produced by a cord having its two ends attached to arms on the fly wheel and itself wrapped more than once round the revolver shaft. The arm to which the after end of the cord is attached is rigid, the other is a spring tightening the fore end of the string with a force approximately equal to the tangential force required when the fly wheel draws the revolver after it. This arrangement causes when motive power is applied to the shaft a much greater force than that of the tightening spring to act on the rigid arm and accelerate the fly wheel, or in place of the fly wheel the arrangement of springs *a* and *b* acting upon shoulders *c* and *d* formed upon the upper end of the connecting rod H, as shewn at Figure 3, Sheet 6, may be used, the projecting shoulders *c* and *d* being so situated that the springs *a* and *b* respectively press against them alternately as the crank pin *e* passes the upper and lower dead centres.

Either of the two keys A or B pressed down alone acts through the treadle on the lever C and presses it down so as to act upon the revolver in the manner described above. The lever C pressed down acts directly as the treadle H is attached to it. The keys A and B in being depressed punch the paper and rise by force either of a stout spring, or of the treadle, or of both. The dot key makes its perforations in the proper line of the dots, the dash key in that of the dashes. The punches may be rigidly attached to the keys or they may move in slides pressed down to cut the paper by the key, and returning by springs. I prefer to connect each punch rigidly with its key. The pin *f* on the revolver which drives the paper shaft is so placed relatively to the crank pin by which the connecting rod H^1 gives motion to the revolver that the paper is at rest for the whole time during which the lowest part of any of the punches is below the upper surface of the paper, it being supposed that the punches move downwards in cutting, any slack therein being taken up by the reaction of the spring guide Q, Figure 2.

In lieu of arranging the instrument in all respects as herein-before described I prefer to dispense with the glass case in which it is enclosed and sometimes not to use chronometric contact, and to adopt the general arrangement illustrated at Sheet 5 of the Drawings. In this arrangement an air turbine driven from a pulley on the revolving shaft *b*, *b*, of the electro-magnetic engine is used to drive a current of dried air through the casing E containing the electro-magnetic engine as well as through the tubular casing B which surrounds the insulating stem bearing the ink bottle and its connections. The turbine is by preference placed in one side of the casing C which contains the driving electro-magnet, and the current of air drawn in by its revolution is discharged up through the floor of the casing E and in part out through perforations *o* in the shield *p* of the conductor W, as shewn, and in part by a pipe *q* leading to the tubular casing B. The air driven through the apparatus may be dried by passing it over sulphuric acid, or other means for depriving air of moisture may be adopted. The result of this application of the turbine is both to prevent dust or shreds from settling on the stems and to keep them dry. The same tubular arrangement allows air to be occasionally forced through by bellows or a hand fanner so as to blow away from the case and stems dust which may have accumulated.

Having now described the nature of my said Invention, and the manner in which the same is or may be used or practically carried into effect I

would observe in conclusion that what I consider novel and original, and therefore claim as the Invention secured to me by the herein-before in part recited Letters Patent is,—

First. The improved arrangement of magnet and signal coil in virtue of which each side of the signal coil is in a magnetic field as herein-before described in place of one side only being in the magnetic field as set forth in my Specification No. 2147, 1867.

Second. The construction in virtue of which the suspended signal coil with the iron core now provided for it can be readily removed, as herein-before described and shewn detached from the instrument at Figures 1 and 2, Sheet 1 of the Drawings.

Third. The improved means of adjusting the signal coil by the use of the torsional elasticity of stretched wires which can be shortened or lengthened and turned and also serve as electrodes, as herein-before described.

Fourth. The improved method of carrying the siphon by attaching it to a stretched wire of sufficient torsional elasticity, as herein-before described.

Fifth. The use of a fine glass tube instead of the siphon, this glass tube having one end fixed to the ink bottle, whilst its outer end is free to be moved by a fibre in consonance with the oscillations of the signal coil, as herein-before described.

Sixth. The appliances for directing hydrostatic pressure to force or suck a cleansing material such as nitric acid through the fixed tube, as herein-before described.

Seventh. Stiffening the marking arm of the tube in one plane by means of one or more stretched fibres acting as stays, as herein-before described.

Eighth. Putting a counterpoise on the siphon to diminish vibrations as herein-before described.

Ninth. Providing a slow motion for the paper when signals are not being received, so as to prevent an accumulation of ink at the end of the siphon or tube, as herein-before described.

Tenth. The use of the electro-magnetic engine first described in combination with the recorder.

Eleventh. The use in combination with my recorder of the special arrangement of replenisher or induction apparatus, herein-before described.

Twelfth. Connecting the motor and the paper drawing gear by hanging pullies so as to diminish vibrations, as herein-before described.

Thirteenth. Regulating the speed of the paper by connecting the drawing rollers with a pendulum in the manner described.

Fourteenth. Marking on the paper the time of day at which it passed through the mechanism, and the arrangement of mechanism for so marking it, as herein-before described.

Fifteenth. Connecting the electrified inductor with the siphon by an adjustable conductor of very high resistance, and by which any excess in the amount may be drained off, as herein-before described.

Sixteenth. Using a dry pile to initiate the electrification of the inductor in my instrument, as herein-before described.

Seventeenth. Using the same motive power as is employed to produce the electric sparks to draw forward the receiving paper in my instrument, also to draw forward punched paper to send signals, in the manner herein-before described.

Eighteenth. Using in my instrument the same paper to send signals and to receive them, as herein-before described.

Nineteenth. Using in my instrument the same paper to record both the sent and received signals by means of a switch and shunt, as herein-before described.

Twentieth. The particular arrangement of connections described in combination with my instrument giving positive and negative signals by two contact springs only, so that the instrument may be used either for sending or receiving signals and the similar arrangement where a greater number of rows of perforated holes are used, as herein-before described.

Twenty-first. The punching apparatus herein-before described.

Twenty-second. The arrangement of mechanism by means of which the paper drawn on by a drum after each perforation begins to move gradually, and after attaining a maximum of speed comes gradually to rest, as herein-before described.

Twenty-third. Pulling back the slack of the paper in the punching machine when necessary by means of an elastic fork, as herein-before described.

In witness whereof, I, the said Sir William Thomson, Knight, have hereunto set my hand and seal, this Twenty-second day of July, in the year of our Lord One thousand eight hundred and seventy-one.

WILLIAM THOMSON. (L.S.)

LONDON:
Printed by GEORGE EDWARD EYRE and WILLIAM SPOTTISWOODE,
Printers to the Queen's most Excellent Majesty. 1871.

A.D. 1871, Jan. 31. N°252.
THOMSON'S Specification

SHEETS
SHEET 1

FIG. 1.

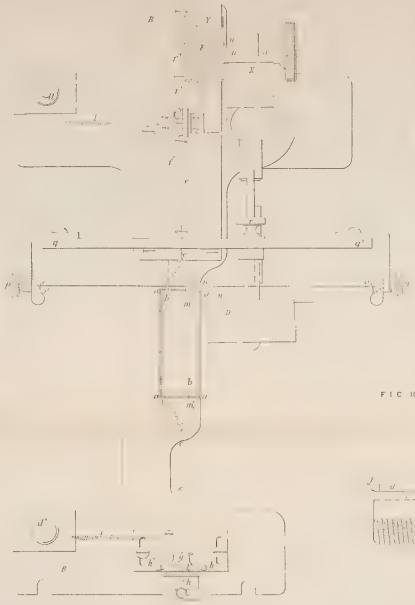


FIG. 2.

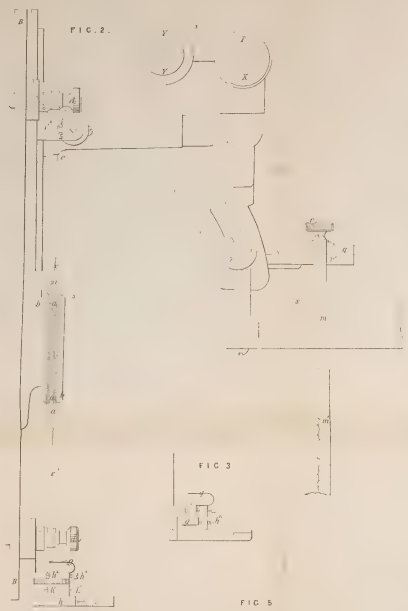


FIG. 3

FIG. 4

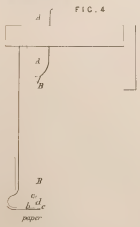


FIG. 5

FIG. 6

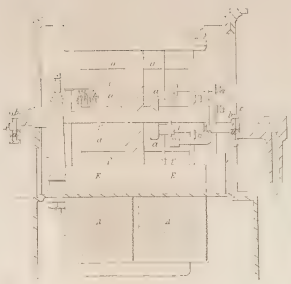


FIG. 7.

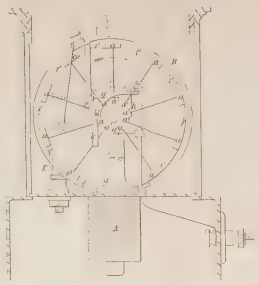


FIG. 8

FIG 10

FIG. 9.

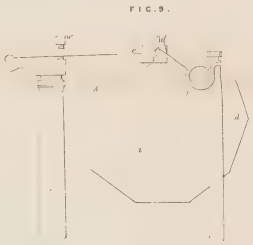


Diagram. FIG. 11.

Diagram. FIG. 5*.

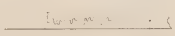
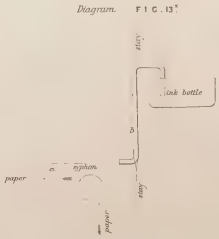


Diagram. FIG. 12

Diagram. FIG. 13.

Diagram. FIG. 13*.



The filed drawing is partly colored

Drawn on Stone by Malby & Sons

LONDON: Printed by GEORGE EDWARD EYRE and WILLIAM SPOTTISWOODE
Printers to the Queen's most Excellent Majesty. 1871

A.D. 1871, Jan. 31. N° 252.
THOMSONS Specification

FIG. 1

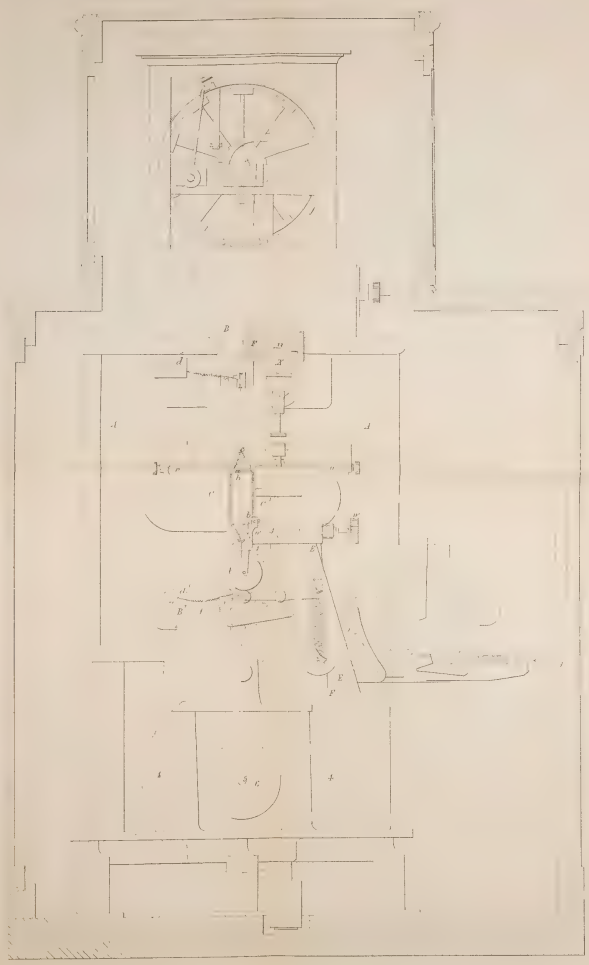
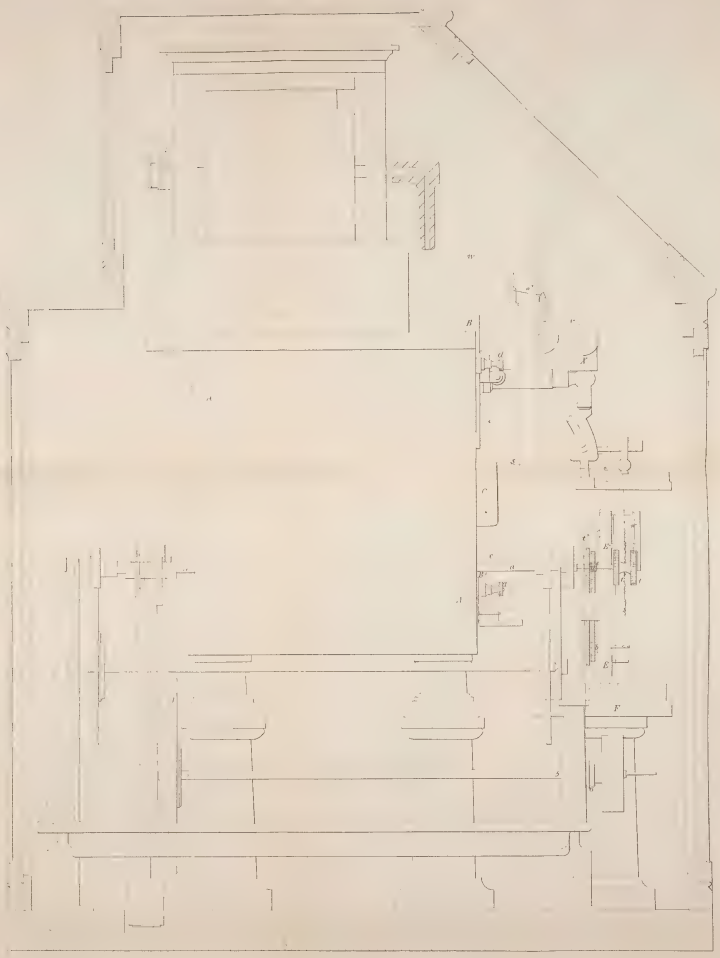


FIG. 2



The filed drawing is partly colored.

LONDON: Printed by GEORGE EDWARD EYRE and WILLIAM SPOTTISWOODE,
Printers to the Queen's most Excellent Majesty. 1871.

A.D 1871. Jan. 31. N° 252.
THOMSONS Specification.

2 SHEETS/
SHEET 2

FIG. 1.

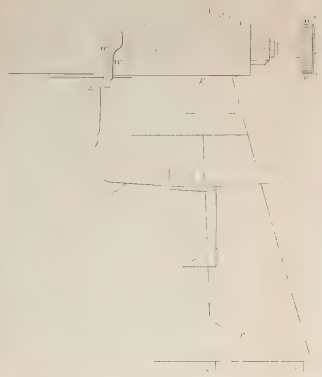


FIG. 3

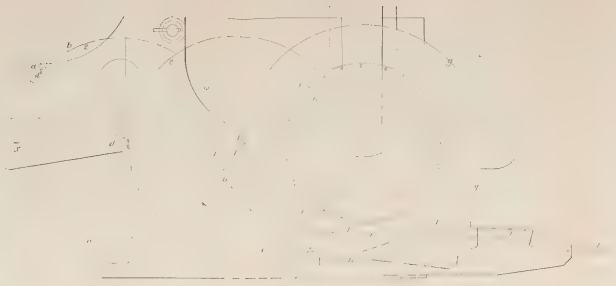
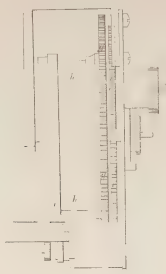


FIG. 5



Earth

Diagram FIG. 8.

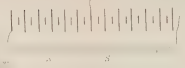


FIG. 4

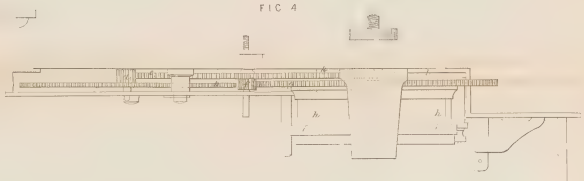


FIG. 2

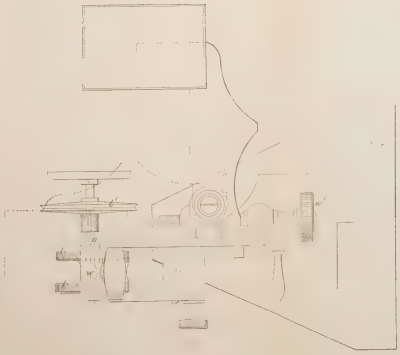


FIG. 6

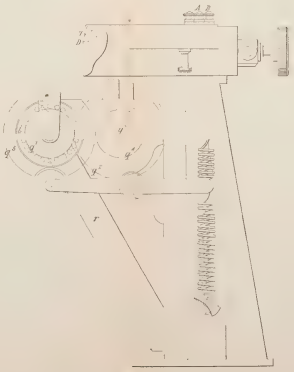


FIG. 7

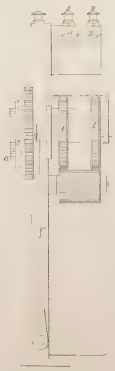


Diagram FIG. 9.

The filled drawing is partly colored.

LONDON: PUBLISHED GEORGE E. EYRE, and WILLIAM SPOTTISWOODE
Printers to the Queen's most Excellent Majesty. 1871

FIG. 1

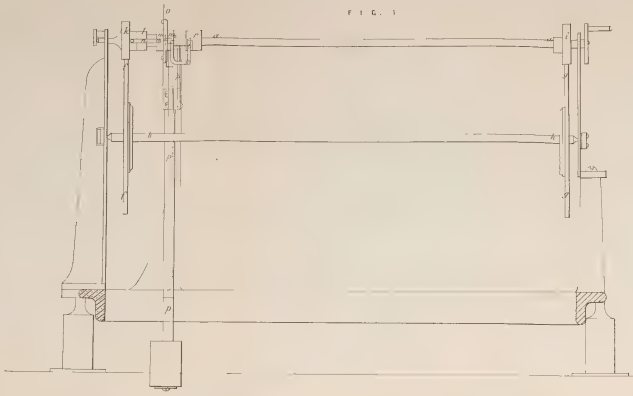


FIG. 4.

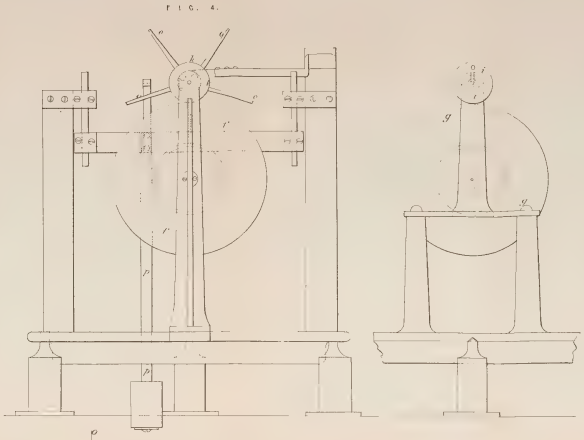


FIG. 3.

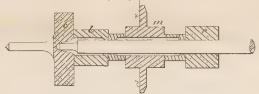
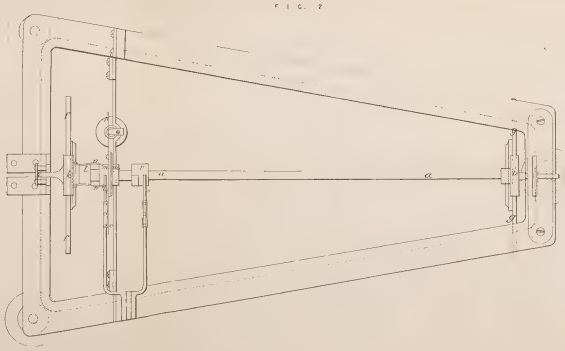
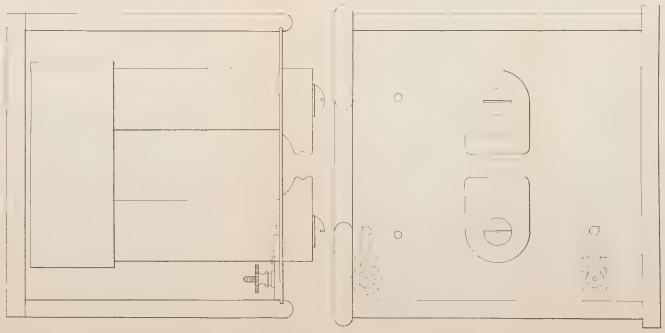


FIG. 2





The filed drawing is not colored.

Drawn on Stone by Malby & Sons

London: Printed by George Edward Eyre and William Spottiswoode
Printers to the Queen's most Excellent Majesty. 1871.

FIG. 1.

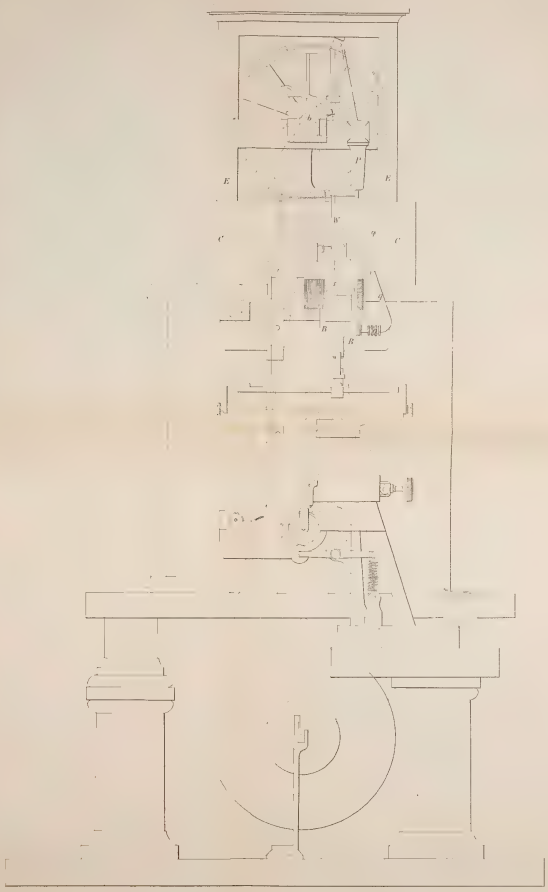
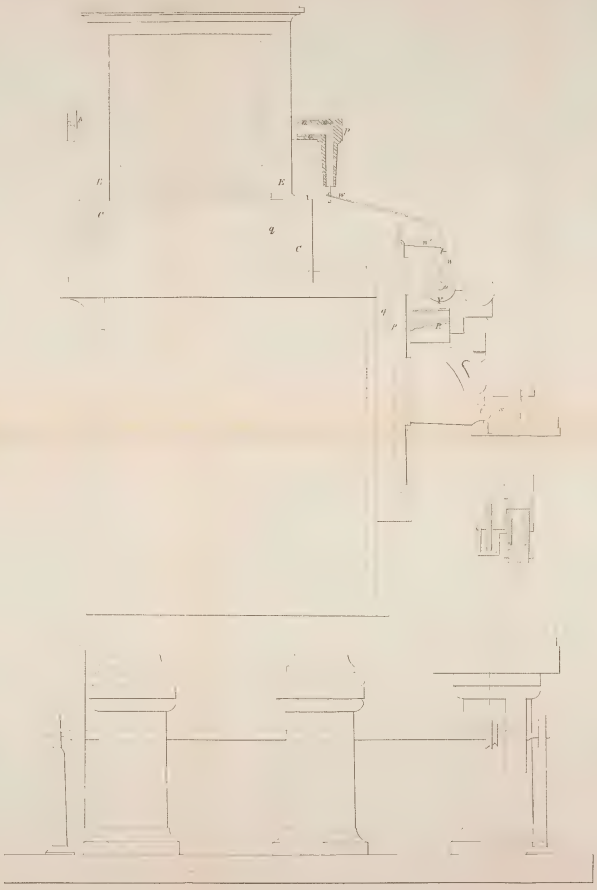


FIG. 2.



The ruled drawing is partly colored.

LONDON: PRINTED BY GEORGE EDWARD EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY. 1871.

A.D. 1871. JAN. 31. N° 252.
THOMSON'S SPECIFICATION.

(7 SHEETS)
SHEET 6.

FIG. 1.

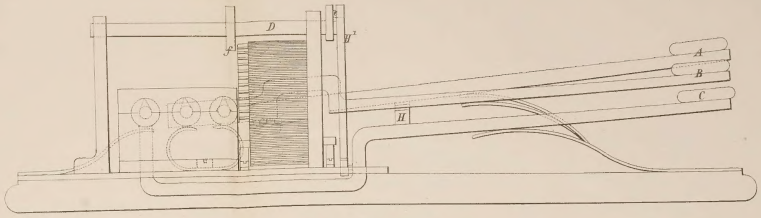


FIG. 2.

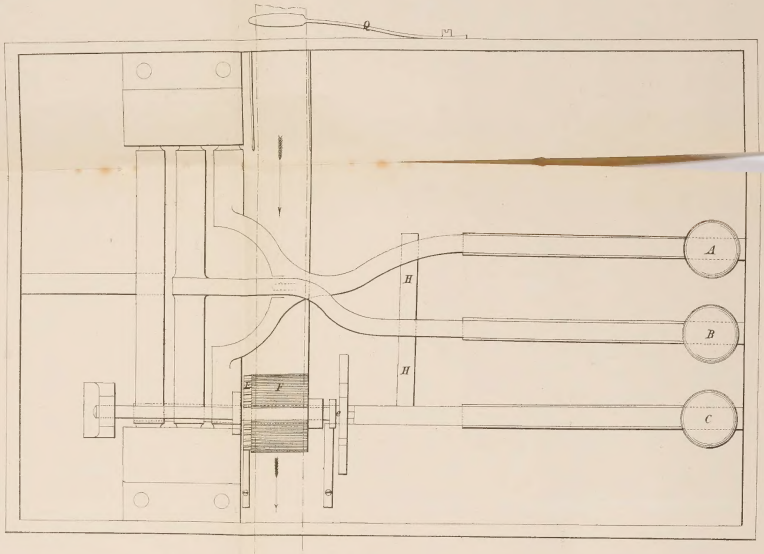
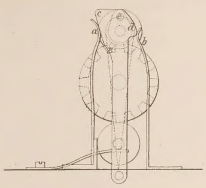


FIG. 3.



The filed drawing is partly colored.

Drawn on Stone by Malby & Sons

LONDON Printed by GEORGE EDWARD EYRE and WILLIAM SPOTTISWOODE

A.D. 1871. Jan 31 No 252
THOMSON'S SPECIFICATION

(7 SHEET)
SHEET 7

FIG. 1

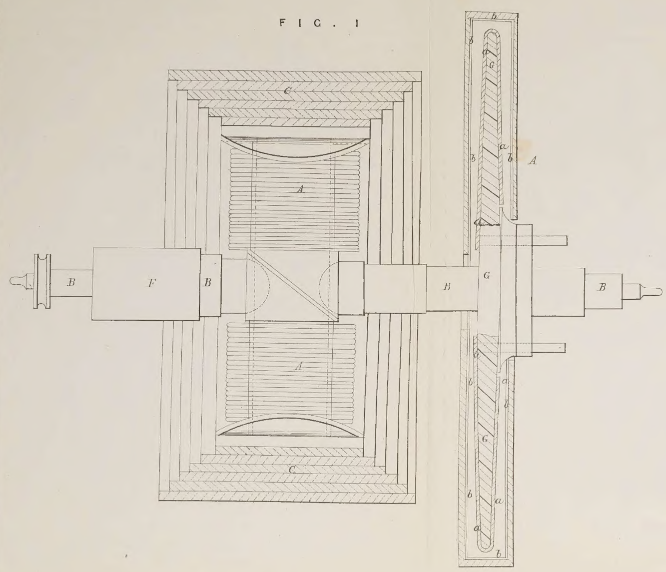


FIG. 2

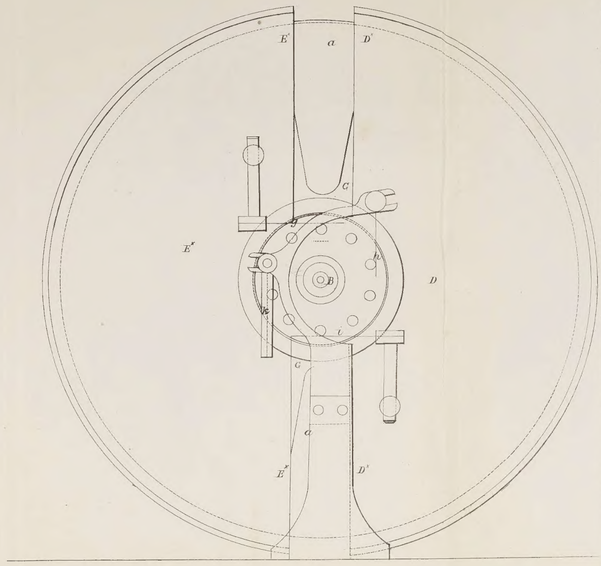


FIG. 3

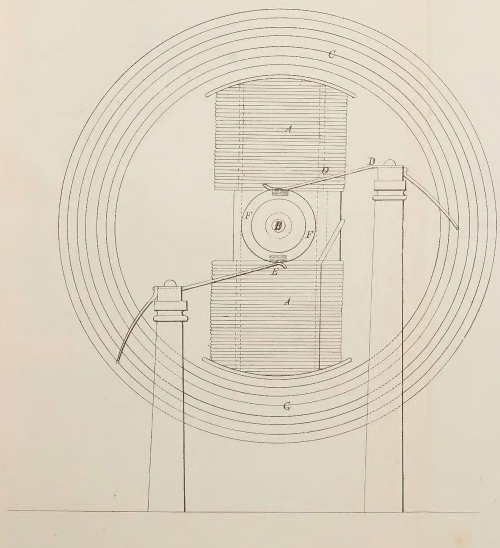
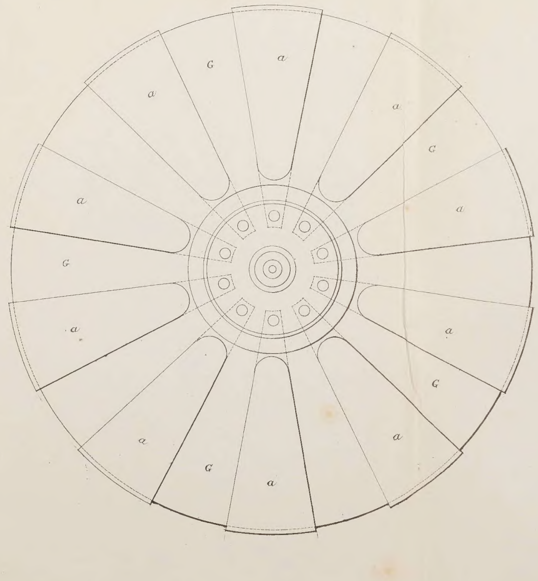


FIG. 4



The filed drawing is partly colored.

Drawn on Stone by Malby & Sons.

London Printed by George Edward Eyre and William Spottiswoode
Printers to the Queen's most Excellent Majesty 1871.